Case Studies For Critically Evaluating Scientific Models
Based On Examples From The History Of Science

Kuhn – Structure of Scientific Revolutions

In his influential *The Structure of Scientific Revolutions* (1962), Kuhn noted that in any particular discipline--physics, chemistry, biology, astronomy, and so forth-- some historical periods are characterized by general consensus about fundamental theories and premises, values, and mathematical and experimental models. Taken together, all these components constitute what he termed a 'paradigm.' In these periods, which he termed 'normal science, scientists apply the same background information (or world view) to their observations and their main activity is 'puzzle-solving.' By puzzle-solving, Kuhn meant they construct experiments and even specific experimental apparatus in order to fill in the details and solve particular problems in the currently accepted theories in their area. He used the term puzzle solving just to indicate that scientists believe there are answers to the problems within the paradigm in the same way that there are always answers to a cross-word puzzle operating within the language in which it was created.

An important feature of periods of normal science is that scientists do not ask fundamental questions about the nature of the universe: Answers to these questions are thought to be provided by the prevailing paradigm. Rather, scientists focus on filling in the details of the paradigm, for example, how broad formulations of natural law function in particular instances.

Kuhn noted that other historical periods lack uniform consensus about a particular paradigm. During these periods, which he terms, 'abnormal science,' the activity of puzzle solving reveals what he called *anomalies* within the paradigm. Kuhn uses the word anomaly to refer to discrepancies between what the paradigm predicts should be observed, and what is actually observed by scientists. When the anomalies become acute enough to raise questions in (particularly young and bright) scientists' minds, competing schools arise which begin investigating fundamental premises of the paradigm. In the most well-known and classic examples, a genius like Copernicus, Newton, or Einstein presents a completely fresh approach in some fundamental area which captivates the younger generation, and as older scientists committed to the previous paradigm pass away, the new paradigm displaces the old and the puzzle-solving activity of normal science begins and continues for the new paradigm.

This displacement of one paradigm by another Kuhn called a scientific revolution. Examples of such revolutions are the displacement of the geocentric astronomy of Ptolemy with the sun centered solar system of Copernicus, or replacement of the phlogiston explanation of why substances burn, with the theory of oxidation.

In the Kuhnian model of scientific revolutions, crucial experiments play a critical role in deciding which paradigm to accept. For example Lavoisier's experiment in which he roasted a metal in a sealed jar and then measured the weight of the residue, confirming many other experiments of weight gain when burning a substance, is often cited as the discovery of oxidation and the downfall of the theory of phlogiston—the theory that

dominated chemistry during the early 18th century which claimed that all matter that could be burned contained a 'burnable' substance called phlogiston, which was released by the burning process. Because releasing substances should lighten the metal's residue, Lavosier's experiment, which demonstrated that the burned residue gains, rather than loses weight, played a crucial role in popularizing the theory of oxidation over the phlogiston theory.

Lakatos – Methodology of Scientific Research Programs

Lakatos argues that the history of science can be best understood as the evolution of a set of theories or hypotheses over time, rather than as either the discovery and corroboration of single theories or the sequential refutation and invention of single hypotheses. He terms the development of these sets, their mathematical techniques and formulas, and their anomalous and corroborating evidence a scientific research programme. He cites the development of Newtonian physics as an example of a scientific research program.

Scientific research programmes are logically characterized by a hard core of theory which remains invulnerable to refutation, and a protective belt of auxiliary hypotheses which are continuously modified in order to account for anomalous evidence. He notes that new theories are always born in a sea of anomalies (which in a naïve falisificationist environment would immediately refute them), but researchers ignore them in expectation that progress over an extended period of time can produce refinements and modifications in initial conditions and auxiliary hypotheses that resolve these anomalies.

An example of this relationship between core and belt theories and how anomalies are dealt with is found in the history of the application of Newton's law of gravity and 3 laws of mechanics to planetary orbits. When this application was initially made, Uranus' orbit did not accord with what was predicted by the Newton's equations. How was this anomaly handled? Scientists working on this application did not consider that Newton's fundamental laws of gravity and mechanics had been refuted. They were a protected core of the research program. Rather, the scientists working on this problem decided to alter auxiliary hypotheses in the belt theory associated with the application of these core equations to planetary orbit. One alteration was the hypothesis that there might be an as yet undiscovered planet that was altering Uranus' orbit. This hypothesis, originally made by Urbain Le Verrier in the 1840s, was not confirmed for another 90[1] years during

[1] Description of the discovery from Wikipedia
In 1906, Percival Lowell, a wealthy Bostonian who had founded the Lowell Observatory in Flagstaff, Arizona in 1894, started an extensive project in search of a possible ninth planet, which he termed "Planet X".[25] By 1909, Lowell and William H. Pickering had suggested several possible celestial coordinates for such a planet.[26] Lowell and his observatory conducted his search until his death in 1916, but to no avail. Unknown to Lowell, on March 19, 1915, his observatory had captured two faint images of Pluto, but did not recognise them for what they were.[26][27] Lowell was not the first to unknowingly photograph Pluto. There are sixteen known pre-discoveries, with the oldest being made by the Yerkes Observatory on August 20, 1909.[28]
Due to a ten-year legal battle with Constance Lowell, Percival's widow, who attempted to wrest the observatory's million-dollar portion of his legacy for herself, the search for Planet X did not resume until 1929,[29] when its director, Vesto Melvin Slipher, summarily handed the job of locating Planet X to Clyde

which time appropriate technologies had to be invented that allowed for appropriate confirming experiments. The core of Newton's theory continued to be research during this time period, however.

Which of these two models of science is correct? What steps would we need to take to answer this question? Understanding and practicing these steps is an important part of what is meant by critical thinking and what we will be learning in this course.

Tombaugh, a 23-year-old Kansan who had just arrived at the Lowell Observatory after Slipher had been impressed by a sample of his astronomical drawings.[29]

Tombaugh's task was to systematically image the night sky in pairs of photographs taken two weeks apart, then examine each pair and determine whether any objects had shifted position. Using a machine called a blink comparator, he rapidly shifted back and forth between views of each of the plates to create the illusion of movement of any objects that had changed position or appearance between photographs. On February 18, 1930, after nearly a year of searching, Tombaugh discovered a possible moving object on photographic plates taken on January 23 and January 29 of that year. A lesser-quality photograph taken on January 21 helped confirm the movement.[30] After the observatory obtained further confirmatory photographs, news of the discovery was telegraphed to the Harvard College Observatory on March 13, 1930.